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Original Article

Determination of Persons at a High Risk of Falling in a Population of Healthy Community-dwelling Elderly Japanese☆

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SUMMARY

Background: Falling is an important social issue for the elderly. This study's aim is to determine useful risk factors that could be used to screen for the elderly at high risk of falling.
Methods: Participants included 965 healthy elderly individuals ≥ 60 years of age (349 males and 616 females; men age: 70.1 ± 7.1 years). We assessed fall risk in these elderly using Demura et al's fall-risk assessment scale (DFRA), which consists of previous experiences with falls and 50 other fall-risk assessment items representing the five risk factors related to the potential for falling, physical function, disease and physical symptoms, environment, and behavior and character (Demura et al., 2010). Receiver-operating characteristics analysis was conducted using previous experiences with falls (faller or non-faller) as the dependent variable and each fall-risk factor score in the DFRA as the independent variable.
Results: The potential for falling was calculated as the highest area under the ROC curve (AUC) (AUC = 0.80; sensitivity = 0.87; specificity = 0.75). However, it was difficult to screen for the elderly as high risk of falling using other fall-risk factor scores.
Conclusion: These results suggest that the potential for falling is a useful risk factor that can be used to screen for the elderly at high risk of falling.

1. Introduction

In an aging society, falling is an important social issue for the elderly[1]. As a result, researchers have closely examined the use of fall-risk assessments in order to prevent falling among the elderly. The results of several performance tests and questionnaires have been reported, and cut-off values that could be used to predict falling in the future (or previous falls) have been proposed[2–4].

To screen for falling based on performance tests, screening criteria have been derived from the relationship between fall occurrence and fall-related physical functions, such as lower limb strength and walking ability. For these procedures, it has been reported that the direct measurement of minimum physical functions requirements for prevention of falls provide a relatively accurate prediction of falling. In contrast, questionnaire-based fall-risk assessments are marked by the simple and comprehensive evaluation of many internal and external risk factors associated with falling.

Falls are caused by multiple factors, and a comprehensive assessment based on these multiple risk factors is important. However, falls occur due to many different reasons, and the causes tend to be highly individualized[5–8]. Especially when screening an elderly population, it is not necessarily the case that there is a clear relationship between the incidence of falls and the outcomes determined by assessing the associated risk factors. Indeed, the score of a questionnaire, which comprehensively assesses fall-risk factors, does not always accurately predict when falls will occur in the future[9].

Both the screening assessment (determining which patients are at high risk of falling from an elderly population and predicting when falls occur) and the risk profile assessment (the identification of problems in specific individuals) are essential for fall-risk assessment. For the risk profile assessment, various risk factors should be comprehensively assessed. For the screening assessment, however, there is no problem with conducting an assessment using a specific factor or variable that can accurately predict the incidence

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of falling. In the case of questionnaire-based fall-risk assessment, a more effective and useful fall risk assessment can be made by discriminating the risk factors associated with being at high risk of falling by creating a fall risk profile.

This study aimed to determine which risk factors from Demura et al's fall-risk assessment scale (DFRA) could be used to screen for the elderly at high risk of falling.

2. Participants and methods

2.1. Participants and data collection

The participants participating in this study were healthy community-dwelling elderly individuals $\geq$ 60 years of age who were living in the Akita, Kanagawa, Ishikawa, Fukui, Nagano, Gifu, Aichi, Tottori, and Fukuoka prefectures of Japan. Mail or field surveys were sent to 1770 elderly participants, of which there were 1317 respondents. Among these, 965 elderly (70.3 $\pm$ 7.1 years) participants, demonstrating a missing values of $<$ 10 percent, were used in further data analysis for this study. This pool of participants was composed of 349 males (70.4 $\pm$ 7.1 years) and 616 females (69.9 $\pm$ 7.1 years), and 160 (16.6%) had experienced a fall in the previous 12 months. There were no particular gender- or age-specific biases between the response and nonresponse participants. The results of this study are generalized due to the limitation of this study sample.

2.2. Fall-risk assessment

DFRA consists of previous fall experiences and 50 fall risk assessment items that represent five risk factors: potential for falling, physical function, disease and physical symptoms, environment, and behavior and character[10]. Potential for falling describes the presence of precursors that are related to falling, such as the act of stumbling. We assessed the potential for falling by asking the participants to answer the following three questions: "Do you stumble often?", "In the past year, have you felt like you might fall down?", and "Have you ever been told that you look like you might fall down?" Physical function was assessed using 22 items selected from three categories (fundamental function, advanced function, and gait) and eight elements (muscular strength, lower limb strength, balancing ability, walking ability, going up and down stairs, changing and holding posture, upper limb function, and gait). Diseases and physical symptoms were assessed using 13 items selected from six categories (dizziness and instances of blackout, medication, sight/hearing and cognitive disorders, cerebral vascular, arthritic and bone diseases, and circulatory disease). The environment was assessed using four items selected from two categories (surrounding environment and clothing). Behavior and character were assessed using eight items selected from four categories (inactivity, frequent urination, fear of falling, and risky behavior).

The validity of DFRA was reported in a previous study[9], and it has been confirmed that this fall-risk scale has a greater discriminative ability in terms of predicting previous fall experiences compared with the Tokyo Metropolitan Institute of Gerontology fall risk assessment chart, which are used widely in Japan. Based on the results of examining the test-retest reliability of DFRA for examining 172 elderly patients, high intraclass correlations were obtained for the total and each risk factor scores, as follow; total score (0.956), potential for falling score (0.904), physical function score (0.957), diseases and physical symptoms score (0.925), behavior and character score (0.923), and environment score (0.874).

All responses were recorded on a dichotomous scale (yes or no), with 1 point assigned to each response in a "high-risk" category. A risk factor score was calculated by summing the scores of the structural items of each risk factor.

2.3. Statistical analyses

Receiver-operating characteristic (ROC) analysis was used to compare the accuracy of each of the fall-risk factors for screening elderly patients at high risk of falling. ROC analysis is a useful tool for statistically confirming the accuracies of several screening methods[11,12].

Because of the cross-sectional setting of this study, ROC analysis was conducted using previous fall experiences (faller or non-faller) as the dependent variable and each fall-risk factor score in DFRA as the independent variable. We performed the ROC analysis on all of the trial models, determined the area under the ROC curve (AUC), and calculated a positive likelihood ratio, 95% confidence interval, and cut-off points that maximized the sensitivity and specificity of each score. A cut-off point was defined as a point with the farthest plots in terms of sensitivity and specificity.

3. Results

Table 1 and Fig. 1 show the results of the ROC analyses and ROC curves for each fall-risk factor. Potential for falling showed the highest AUC (0.80; 95% CI: 0.76–0.83) and sensitivity (0.87) values. The AUC values of the other risk factors were $<$ 0.70. Most notably, it is difficult to distinguish the elderly at high risk of falling solely by environment, which demonstrated the lowest AUC value (0.54).

4. Discussion

This study's aim was to determine useful fall-risk factors through ROC analysis that could be used to screen for the elderly at high risk of falling. ROC analysis is a useful statistical tool that can determine the most useful screening test from several tests and set criteria (cut-off points) for screening. The AUC, which is calculated in ROC analysis, is an indicator of discriminant power, and it is interpreted by the following guidelines: noninformative test equal to chance, AUC = 0.5; less accurate, 0.5 $<$ AUC $<$ 0.7; moderately accurate, 0.7 $<$ AUC $<$ 0.9; highly accurate, 0.9 $<$ AUC $<$ 1.0; and perfect discriminatory test, AUC = 1.0[13,14]. In previous studies, an AUC of 0.8 has been reported as a reasonably powerful model[15].

Of the fall-risk factors determined in this study, a sufficient AUC value was only found for potential for falling (0.80), and lower AUC values were determine for all other fall-risk factors (physical function: 0.63; diseases and physical symptoms: 0.63; environment: 0.54; behavior and character: 0.67). A similar trend was reported in a previous study, which attempted to determine the elderly at high risk of falling based on discriminant analysis[9]. Thus, the highest discriminant probability was obtained for potential for falling, but it was difficult to discriminate the elderly at high risk of falling using the other four risk factors (physical function, disease and physical symptoms, environment, and behavior and character).

Table 1
Summary of ROC analyses for each fall risk factor.

Risk factors	AUC	*p*	AUC (95% CI)	Sensitivity	Specificity	Cut-off value
Potential for falling	0.80	0.00	0.76 ~ .83	0.87	0.66	1
Physical function	0.63	0.00	0.58 ~ .68	0.40	0.81	10
Diseases and Physical	0.63	0.00	0.58 ~ .67	0.30	0.87	5
Behavior and Character	0.67	0.00	0.63 ~ .72	0.53	0.75	3
Environment	0.54	0.12	0.49 ~ .59	0.78	0.27	1

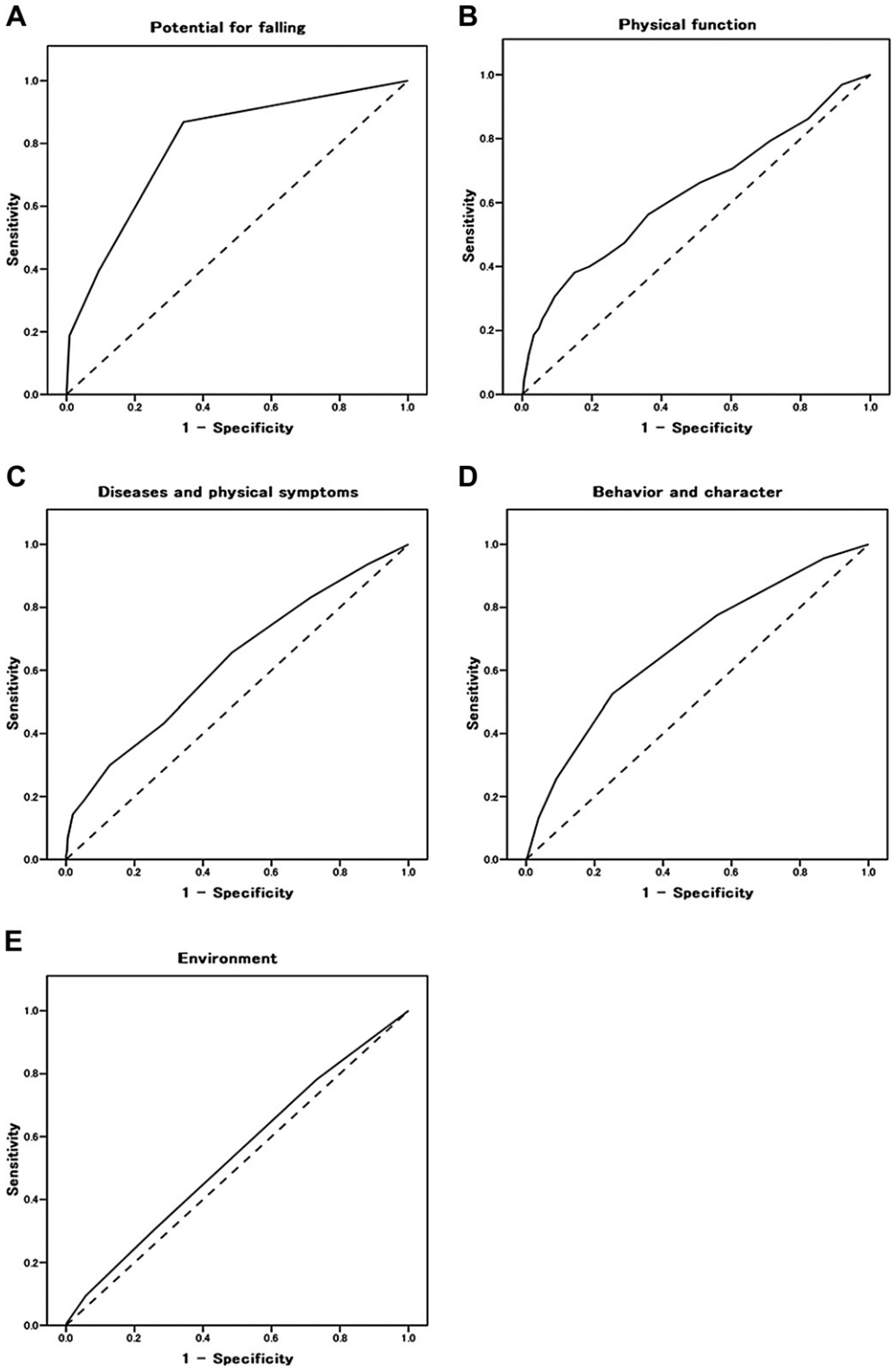

Fig. 1. ROC curves of each fall risk factor.

In this study, the sensitivity coefficient of the potential for falling (0.87) was higher than those of the other risk factors, but the specificity value of the potential for falling was not very high (0.66). Sensitivity refers to the proportion of participants who have the target condition (reference standard positive) and demonstrate positive test results. Specificity refers to the proportion of participants without the target condition who demonstrate negative test results[11]. When assessing fall risk among an elderly population, high sensitivity corresponds to a high negative predictive value (proportion of "true negative"/("false negative" + "true negative"), and it should be given a high priority in comparison with high specificity. Thus, moderate specificity should be considered within the allowance of the fall-risk assessment.

Falling is a multifactorial problem, and the causes of falling are highly individualized[5–8]. Therefore, on the questionnaire-based fall-risk screening of the elderly population, clear relationships between the number of falls and risk factor scores may be invisible. However, potential for falling means the likelihood of falling, and this indicates a strong relationship with falling regardless of the causes for being at high risk. It is considered a useful measure for screening the elderly at high risk of falling. Although the assessment of potential for falling provides information concerning the likelihood of falling, it cannot provide information about the causes of falling or countermeasures that could be used to prevent falls in the future. To prevent falls, both assessment of the risk level (screening) and a risk profile are essential. Therefore, a fall-risk prolife assessment that contains comprehensive internal and external fall risk factors is also important when screening the elderly at high risk of falling.

5. Summary

Assessment based on the score of potential for falling is a useful tool for screening the elderly at high risk of falling, although it is difficult to screen them using the scores of the other risk factors. However, the assessment of potential for falling provides useful information that can be used to determine the fall-risk level, but it cannot be used to determine its causes and countermeasures. It is important to screen for the elderly at high risk of falling in order to make assessments based on individualized risk profiles.

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